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THE UNDEVELOPED MINERAL RESOURCES OF PENNSYLVANIA

INTRODUCTION

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THE OUTLOOK IN PENNSYLVANIA TODAY

Pennsylvania has reached a crossroad in her industrial development. Her position near the eastern seaboard, her initial heavy forests and rich mineral deposits, combined with a high degree of enterprise on the part of her citizens, have given the State an industrial preeminence out of all proportion to her size. Though only thirty-second in size among the States, she stands second in population, wealth, and industry.

Thoughtful observers, however, have noted a turn in the tide. Pennsylvania's population, though increased between 1920 and 1930, has not maintained the same rate of increase that it held for half a century or more. Had the former rate held, the State would have had 613,875 more people than the census revealed. Between 1899 and 1919 the value of manufactured products in Pennsylvania increased from $691,581,108 to $3,105,294,239, or at a rate of $121,000,000 a year. From 1919 to 1927 there was a decline in this value. In 1929 the value was $3,430,605,526, or a gain for the ten years of only $32,500,000 a year. From 1910 to 1920 thirteen counties in the State declined in population. From 1920 to 1930 population declined in nineteen counties. The once great lumber industry in Pennsylvania has long passed its zenith. The anthracite industry, which in 1917 produced 99,611,811 short tons and in 1923 93,339,000 tons, valued at $507,000,000, by 1930 was down to 69,385,000 tons valued at $354,000,000, and in 1932 to about 49,500,000 tons. The production of bituminous coal, that in 1918 reached 178,551,000 tons and in 1923 171,880,000 tons valued at $472,217,000, had declined by 1930 to 124,462,787 tons valued at $213,584,000, and in 1932 to 74,128,000 tons. Likewise, the number of men employed in the bituminous industry in Pennsylvania fell from 194,981 in 1923 to

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130,150 in 1930. The metal and metal products industries in 1918 employed 608,189 people and in 1929, at the height of the boom, only 466,920.

These few figures are simply indicative of changes going on. But they are of such a character as to raise serious inquiry as to the causes and ultimate effect of such changes if continued. Without attempting to answer these questions here, they lead to the question: "Does the State have undeveloped mineral resources that could be used as a basis of new industries to take the place of those showing the greatest decline?" It is to answer this question, so far as present knowledge permits, that the chapters on the several minerals and on the mineral resources of each county will be prepared.

FINDING MINERALS OF VALUE

There is widespread belief among those not acquainted with geology that any mineral may or might occur anywhere, that it is a matter of chance whether it does or does not occur in any particular spot, and that the problem is simply to find out if it occurs. On the contrary, geologists recognize that most mineral resources occur only under certain definite, recognizable conditions, different for different minerals. Even a general knowledge of the rock structure and history of a given area makes it possible for a geologist to predict that certain minerals do not occur in this area; that certain other minerals may occur there and might profitably be looked for; that other minerals almost certainly do occur there and it is only a question of the quality, quantity, lay, etc., factors which may materially affect the value.

Thus a geologist acquainted with the general geology and history of Pennsylvania, if asked regarding the mineral resources of Lancaster Township in Lancaster County, would at once list coal, oil, and gas as among the things certainly not to be found in that township. He might list trap rock, lead and zinc ores, as possibly occurring in the township though not as yet known or found. He would list limestone as certainly occurring there, and quartzite, phyllite, and other rocks as occurring at a depth of 2000 feet or less.

For large parts of the State, geologists with a general knowledge of the geology of the State, acquired as a result of the work of the State Geological Survey, can tell with much certainty and to a depth of 10,000 feet, the general character of all of the rocks underlying any tract of land and what associated minerals may or may not occur there also. In other areas, the rocks have been so broken and mixed together that geologists would hesitate, without a personal examination on the spot, to say what rocks or minerals do or may occur at or under that spot. Even for such places, however, an organization like the Geological Survey with its accumulated records may venture to tell, even without such personal study in the field, that certain materials do not occur and that certain others may or do occur.

As will be pointed out beyond, to be a mineral resource a deposit must occur in such a location and position or within such a depth in the earth and with such quality and quantity as to make possible its profitable exploitation. Even gold may occur in visible particles in a rock and yet not be a mineral resource for the reason that it would cost more to mine and crush the rock and recover the gold than the gold is worth after its recovery.

However, while a land owner in Lancaster Township may be interested to know that coal, oil, and gas do not occur under his land, and

while that knowledge may save him from large financial losses, he is likely to be more interested in what is under his land. It is here that detailed geologic and mineral resource surveys are of value, and that a State Geologic Survey justifies itself; for such a Survey makes a single systematic examination, covering all phases of the geology and mineral resources, and once published, this is available to every one, whether small farm owner or a financier proposing to develop some mineral resource occurring in the area.

Preliminary to taking up the several mineral resources, it is well to note that a mineral becomes a mineral resource only when it fulfills certain conditions.

WHAT CONSTITUTES A MINERAL RESOURCE

A rock or mineral is not a resource unless it has present or potential commercial value. It must be remembered that the production of mineral products, like that of other products, has been overdone to the point that few mineral products today yield an adequate return on the investment unless especially favored in quality, low cost of mining, nearness to market or other factor. The value of a mineral in the ground depends entirely on the reasonable expectation of its profitable exploitation. Minerals are exploited either through ownership or by a lease on a royalty. Royalties are based on anticipated revenues. A man or a company will not lease the mineral rights on a body of mineral unless it can be exploited at a profit. If experience shows that the mineral body cannot be exploited at a profit, it loses all value as a mineral resource either for development or taxing.

These matters are cited merely as a caution against embarking in new mining enterprises without competent advice, advice which as a rule can be given only after a study on the ground. This Survey can give only general advice. It cannot and may not take the place of the consulting geologist, who studies and advises on the conditions existing at the very point of proposed exploitation.

The geographic elements are today most often the determining factors in the success or failure of a mining venture. Present high freight rates form so large a part of "delivery cost" of most mineral products, because of their bulk and weight, as to require most careful consideration. The margin of profit all through the mining industry is so low that a difference of 10 or 15 cents in the freight rate may spell success or failure. One of the very first steps in any mining venture is, therefore, to locate on a map the marketing points for the mineral at issue. Then, to note on the same map the present sources of supply and the proportions received from the different sources. If it be found that the nearest markets are already being amply supplied, the only possibility of successfully breaking into such markets is through superior preparation, reduced prices made possible because of favorable mining conditions, superior management and methods, or through the discovery or invention of new market uses.

COST OF DEVELOPING MINERAL RESOURCES

In estimating the probable cost of a proposed mining development, the following are a few of the principal items to be taken into account: (1) options on land to be studied; (2) prospecting, test drilling, analyses, etc. to determine the character, thickness, depth and lay of the deposit, and to insure that these meet the need, as indicated beyond;

(3) purchase of lands (if not already owned), rights of way, etc.; (4) cost of opening mine, surface buildings, mining equipment, building railway connections, etc.; (5) cost of operating mine to the point of first financial return. These are investment costs and must be recovered with interest, preferably in the early years of the mine, otherwise they are likely to be lost in the increased cost as mining gets deeper or farther from the opening. In general the average investment in a mine is about double the annual gross value of the product; that is, a mine producing 1,000,000 tons a year, valued at $2,000,000, will cost about $4,000,000.

After operation is established, mining costs consist of mining labor, supervision and management, supplies, repair and replacement of tools and machinery, and building, accident, fire, and liability insurance, upkeep during idle time, safety work; if not near a large town, probably entertainment, possibly work insurance and pensions.

Costs may be summed as follows:

1. Interest on capital cost.
2. Amortization of capital cost.
3. Mining and preparation costs.
4. Transportation cost.
5. Marketing costs.
6. Taxes; local, State, and Federal.

If these when added together are less than the market price, the rest is profit available for dividends and surplus.

The purpose of the preliminary prospecting and testing is to determine: (1) that the mineral deposit has such character, grade, or other qualities as to make it suitable for use in meeting some existing market demand or for some new use just discovered. In a coal bed, differences in sulphur or ash content, in the fusion point of the ash, or some other quality may determine whether it is of value or not. Color in a building stone or of clay when burned may determine its value. (2) The deposit must be large enough to return the investment cost of production. For example, if the capital cost of a mine is $50,000 and the sale price of the mineral will permit an amortization charge of 10 cents a ton, 500,000 tons must be mined in order to return the investment regardless of profit. (3) Mining costs will largely be determined by the position of the deposit in the ground, its size, shape, etc. Thus, a deposit at the surface, a 4-foot coal bed, or a solid coal bed, might be minable when a deposit at depth, a 2-foot coal bed, or a coal bed with partings would not. It costs about twice as much to mine a 2-foot bed as compared with a 4-foot bed of coal or a vertical bed as compared with a horizontal bed. Two ore bodies may each contain a million tons of ore, but one is compact and minable, the other strung out and unminable.

All of these factors should be known and carefully considered before opening a new mine or investing in somebody else's mine.

THE VALUATION OF MINERAL LANDS

The Pennsylvania Supreme Court has ruled that the value of mineral lands is to be determined by sale prices in the same manner as other real estate.

There are, however, many instances where this rule is inadequate:

1. In a district where there have been no previous sales.

2. In a district where conditions affecting the value of the mineral lands have changed materially since the last sale.

3. Where previous sales have been between buyer and seller not equally informed as to the quality and quantity of the mineral resources and, therefore, the sale does not represent a fair bargain.

4. No two parcels of mineral lands even though adjoining were ever exactly alike. The prudent buyer or seller, therefore, will always seek to determine the value of any tract independently of the price of any other tract.

It is always possible to arrive at a fair valuation of a mineral tract if a reasonable amount of information exists regarding the mineral on the tract. The basis of such a valuation is always the market price of the mineral at the point of consumption.

Subtracting from this market price the cost of transportation and marketing will give the value f. o. b. cars at the nearest shipping point. The value of the mineral in the ground is determined by the margin between f. o. b. value and the sum of capital costs and mining or operating costs as previously described.

Suppose, for example, we are trying to determine the fair value of a tract of coal land, and find that the average sale price at the nearest point of consumption for the last five years has been $4.80 a ton, and local royalties 10 cents a ton. Suppose it is found that the costs of selling and delivery average 90 cents, freight is $2.00 a ton, capital costs 20 cents a ton, mining costs $1.40, total cost $4.50, margin 30 cents, which allows 20 cents for profit and 10 cents a ton for the coal in the ground.

Starting with 10 cents a ton as royalty or as the value of the coal in the ground the day it is mined, what is an acre of coal worth today? Suppose that prospecting has indicated that the tract of land, 1,000 acres in extent, contains (an estimate) 6,000,000 tons of recoverable coal, or an average of 6,000 tons per acre; and that it is planned to recover the coal at a rate of 100,000 tons a year, or say 16⅔ acres a year. At that rate it will require 60 years to mine out all of the coal or an average of 30 years for all acres. But 10 cents, at 6 per cent compound interest for 30 years, will be worth 57.4 cents. Inversely, 10 cents 30 years from now has a present value of 1.66 cents. But from that must be subtracted the taxes from year to year at say 2 per cent. Then allowance must be made for the possibility that actual mining will reveal less coal than was indicated by prospecting. On the whole it may prove that one cent a ton or $60 an acre is a fair price for the coal in the ground under the land today, assuming that mining is just starting. If it appears likely that the coal will not be mined for many years the value decreases accordingly. If the land is far from a railroad and it is quite uncertain when the coal will be mined, the coal may have little or no value today.

TAXATION OF MINERAL RESOURCES

In the past, taxation of Pennsylvania's undeveloped mineral resources has filled the coffers of many of the counties, paved roads, taught children, built courthouses and bridges. Today with many, if not most, of the State's mineral industries operating on a no-profit

basis or on very small profits, these resources have very small value, usually far below the assessed value. Thousands of acres of coal lands are said to have been turned back to the counties in lieu of taxes.

Tax rates, carried over from other days when the mineral industries were prosperous, are a great handicap to those same industries today when they are struggling to keep alive. To reduce the tax rate will cripple the counties in their efforts to meet the service demands of their citizens. The answer appears to be a "severance tax," that is, a straight tax on the gross value of the several minerals as they are removed from the mine, quarry, or well. Such a tax is levied in proportion to the mineral removed, at a time when the sale of that mineral makes the operator best able to pay the tax. Strictly such a tax is in the nature of a deferred land tax, and may be computed on that basis. It avoids all the uncertainty as to the quality, quantity, etc. of a mineral in the ground. If the tax is based on the gross receipts from the sale of the mineral, it automatically adjusts itself to the changing values of the minerals taxed, and taxes all minerals equally.

LIST AND CLASSIFICATION OF THE MINERAL RESOURCES OF PENNSYLVANIA

The statement is often made that Pennsylvania produces more minerals than any other State, not only in quantity, but in kinds and variety. This is sometimes embellished with the claim that Pennsylvania could, if shut off from the rest of the world, supply all her needs from her own rocks. Unfortunately, this is not true. Thirteen States produce a longer list and greater variety of minerals than does Pennsylvania. California produces almost twice as many.

The U. S. Bureau of Mines, in its annual summary of the mineral resources of the United States, lists 92 minerals and mineral products; of these, only 26 are being mined in Pennsylvania today; 5 are being recovered as by-products, and 21 have been mined in the past, mostly on a very small scale, leaving 40 minerals or almost one-half of the list not known to occur in Pennsylvania in commercial quantities. In other words, of 92 minerals and mineral products listed in the United States, Pennsylvania produces only 31 and has produced 21 others, a total of 52.

As to variety, over 99 per cent of the value of mineral production of Pennsylvania consists of fuels and structural materials. Of this 99 per cent, 73 per cent stands for coal, 10 per cent for oil and gas, and 16 per cent covers cement, clay and slate, stone, sand and gravel, leaving less than 1 per cent for the metallic ores and all other minerals. At present iron is the only metal mined in Pennsylvania, though copper, gold, and silver are recovered in small quantities as by-products in the concentration of the iron ore. By contrast, California, for example, mines chromite, copper, gold, iron, lead, manganese, mercury, platinum and allied metals, pyrite, silver, tin, and tungsten. As against Pennsylvania's feldspar, talc and "tripoli," California produces asbestos, asphalt, barite, bromine, calcium-chloride, diatomite, feldspar, gypsum, iodine, lithium minerals, magnesite, marl, pumice, salt, sericite, sodium salts, sulphur ore, and talc.

Pennsylvania's preeminence, therefore, lies not in the number or variety of her minerals, but in the extent and multitude of her mining operations, a preeminence she acquired early in the last century and has maintained to the present, though not to the same degree. In 1930 Pennsylvania produced 18.26 per cent of the total value of the mineral

production of the United States. In 1928 it was 19.11 per cent. In 1923 it was 23.60 per cent, or nearly one-fourth of the total and almost equal to the sum of the three next higher States, which it did exceed before 1922. In 1902 Pennsylvania produced almost 30 per cent of the mineral values of the United States.

If individual minerals be considered, some interesting facts are revealed. Until about 1870 Pennsylvania produced 70 per cent of all the coal mined in the United States. In 1837 the ratio was 86 per cent; by 1880 the ratio had dropped to 65 per cent; by 1890 to 56 per cent; by 1900 to 51 per cent; and in 1930 Pennsylvania produced only

PENNSYLVANIA'S RANK AMONG THE STATES IN VALUE OF LEADING MINERAL PRODUCTS

1927

(FIGURES IN THOUSANDS OF DOLLARS)

THE TWENTY FIVE LEADING MINERAL PRODUCTS (In Order)	UNITED STATES	FIRST	SECOND	THIRD	OTHER
COAL	1,450,599	693,655	W.Va. 249,730	Ky. 119,249	
BITUMINOUS	1,029,657	273,714	W.Va. 249,730	Ky. 119,249	
ANTHRACITE	420,941	420,941			
PETROLEUM	1,172,830	OKla. 347,100	Texas 249,800	Calif. 241,500	5th 32,900
IRON, PIG	646,226	212,179	Ohio 150,125	Ill. 66,442	
IRON ORE	151,125	Minn. 87,935	Mich. 37,135	Ala. 12,973	6th 2,559
CLAY PRODUCTS	403,363	Ohio 92,363	50,909	N.J. 43,073	
CLAY SOLD	13,697	2,403	Mo. 1,693	Ga. 1,537	
NATURAL GAS	317,930	W.Va. 67,994	Calif. 50,946	49,135	
CEMENT	281,735	66,711	Calif. 26,623	Mich. 20,838	
COKE	262,320	67,170	Ind. 37,152	N.Y. 24,125	
COPPER	220,609	Ariz. 89,366	Utah. 33,658	Mont. 29,277	12th 227
STONE	198,647	Ind. 22,664	18,999	Ohio. 16,769	
NATURAL GASOLINE	118,688	Calif. 52,436	OKla. 29,114	Texas 18,347	10th 1,648
SAND	112,271	N.Y. 12,157	12,040	Ill. 9,166	
LEAD	84,208	Mo. 25,043	Idaho 21,838	Utah 19,061	NONE
ZINC	73,851	OKla. 40,885	Mont. 10,269		
FERRO-ALLOYS	55,163		N.Y.	Ohio	No figures
GOLD	45,418	Calif. 11,679	S.Da. 6,670	Alaska 5,918	16th 62
GYPSUM	42,174	N.Y. 14,889	Iowa 6,713	Ohio 5,041	NONE
LIME	38,638	Ohio 9,497	6,105	Mass. 2,325	
SULPHUR	38,300	Texas 38,000	La.		NONE
SILVER	34,266	Utah 10,973	Mont. 6,696	Idaho 5,062	18th 11
ZINC & LEAD PIGM.	25,275		Ohio	Ill.	No figures
SALT	24,817	Mich. 7,551	N.Y. 6,121	Ohio 3,130	NONE
SLATE	11,380	4,769	Vt. 4,108	N.Y. 812	

Figure 1

36 per cent of the total. Pennsylvania and a small adjoining area in New York produced all of the petroleum in the United States, or 100 per cent, until 1875. In 1913 this State produced only 3.20 per cent, and in 1930 only 1.1 per cent of the total in the United States.

The rank of Pennsylvania in the 25 leading mineral products of the United States is shown in the chart giving the figures for 1927. Note that Pennsylvania produces all but 4 of these mineral products and takes first place in 10, second place in 4, and third place in 2, or it has first, second, or third place in 16 out of the 25.

In Figures 1 and 2 data for 1927 are used because they are more representative of the industries than figures for 1932, which are not available when this paper goes to press.

PENNSYLVANIA'S SHARE OF NATIONAL MINERAL PRODUCTION

(VALUE IN MILLIONS OF DOLLARS)

		1914	1919	1923	1927
TOTAL	U.S.	2.433	4.595	5.986	5.529
	PA.	452 (18.6%)	918 (20.0%)	1.223 (20.4%)	936 (16.9%)
COAL	U.S.	681	1.525	2.021	1.450
	PA.	347 (50.9%)	730 (47.9%)	979 (48.4%)	693 (47.8%)
CEMENT	U.S.	80	147	259	281
	PA.	20 (25.0%)	43 (29.2%)	69 (26.6%)	66 (23.5%)
CLAY PROD.	U.S.	164	275	424	403
	PA.	21 (12.8%)	39 (14.2%)	58 (13.7%)	50 (12.4%)
NATURAL GAS	U.S.	94	160	240	317
	PA.	20 (21.2%)	31 (19.3%)	45 (18.7%)	49 (15.4%)
PETROLEUM	U.S.	214	760	978	1.172
	PA.	15 (7.0%)	33 (4.3%)	25 (2.5%)	29 (2.4%)
STONE	U.S.	77	96	159	198
	PA.	8 (10.3%)	16 (16.6%)	18 (11.3%)	18 (9.0%)
SAND & GRAVEL	U.S.	22	45	90	115
	PA.	2 (13.4%)	5 (12.2%)	9 (10.0%)	12 (10.4%)
SLATE	U.S.	5	6	12	11
	PA.	3 (64.1%)	2 (41.1%)	5 (46.7%)	4 (41.2%)

Figure 2

Figure 2 shows the changing production figures and the percentage between 1914 and 1927. Percentages are given in the small keystones. Notice that the percentages of all of these products decreased between 1914 and 1927 although the total production may have increased greatly. These figures should be compared with the detailed figures of 1930 in the next table.

Mineral production of Pennsylvania in 1930

[U. S. Bureau of Mines]

		Quantities	Value	Total
Fuels				
Peat	Tons	(6)	(6)	
Anthracite	"	69,384,837	$354,574,191	
Bituminous coal	"	124,462,787	213,584,000	$568,158,191†
Briquets	"	133,922	(a)833,104	
Coke (b)	"	14,540,579	(a)54,098,236	
Natural gas	M. Cu. ft.	88,706,000	44,521,000	
Natural gasoline	gals.	16,713,000	1,229,000	
Petroleum	bbls.	12,803,000	33,410,000	79,160,000†
Structural materials				
Cement (c)	bbls.	37,968,647	52,712,176	
Clay products			38,336,710	
Clay raw	tons	801,553	(a)1,965,186	
Sand and gravel		11,012,512	11,107,825	
Sand lime brick	1000's	(e)	(e)	
Slate			3,634,258	
Stone	tons	15,137,560	17,822,706	125,578,741†
Metallic minerals				
Copper (d)	lbs.	2,859,675	371,758	
Ferro-alloys	long tons	340,475	(a)29,827,790	
Gold (d) (e)	troy oz.	630	13,023	
Iron ore	long tons			
Sold to furnaces	" "	894,039	1,850,661	
Sold for paint	" "	(1) (5)	(a) (e)	
Iron, pig	" "	9,734,511	(a)176,521,843	
Silver (d) (e)	troy oz.	5,762	2,218	
Mineral paints	tons		(e)	2,237,660†
Other minerals				
Feldspar, (crude)	long tons	(e)	(e)	
Gems & precious stones			(f)	
Lime	tons	633,520	4,661,670	
Mineral waters			(f)	
Sand & sandstone (finely ground)			(e)	
Sulphuric acid	tons	141,506	(a)1,362,703	
Talc	"	(e)	(e)	
"Tripoli" (h)	"	(e)	(e)	
Miscellaneous			(g)8,963,050	5,354,015
Total value, eliminating duplications				$778,523,421

(a) Value not included in value for State.

(b) Exclusive of beehive coke, value for which is included under miscellaneous, but not in total for State.

(c) Exclusive of natural cement, included under miscellaneous.

(d) Copper, gold and silver were recovered from pyritiferous magnetite of which 1,601,824 short tons were mined.

(e) Value included under miscellaneous.

(f) No canvas.

(g) Includes beehive coke, and mineral paints (zinc and lead pigments) which are not included in total.

(h) This product is finely pulverized shale, not true tripoli.

In addition the following minerals or mineral products have at one time or another appeared among the list of commercial minerals obtained in Pennsylvania: Asbestos, barite, bromine, chromite, garnet, graphite, grindstones, lead, magnesite, manganiferous ore, micaceous minerals, millstones, nickel, pebbles for grinding, phosphate rock, pyrite, salt, sand lime brick, zinc.

HOW THE PRESENCE OR ABSENCE OF MINERALS IN ANY AREA IS DETERMINED

In Pennsylvania most of the mineral wealth is in bedded deposits or rock formations, as coal, limestone, cement rock, slate, and ganister. Even the oil and gas are so closely related to certain rock beds that the driller seeks to drill the hole to a certain sandstone or "sand" in which it is expected the oil or gas may be found, rather than drilling haphazard to any depth. Deposits of ores and minerals in veins and masses, as magnetite and feldspar, are few in Pennsylvania. So, determining the mineral wealth means determining the presence or absence of certain bedded rock formations.

If all the rock beds forming the earth's crust lay flat and the surface also was flat, shafts and drill holes would have to be sunk to find what is below the surface. Fortunately for our purpose, the rock beds lie in waves or folds, some of them very minor, others that must originally have been several miles high. Since the time of folding, rains and rivers have worn down the folds and exposed the edges of the beds to a thickness of 25,000 to 30,000 feet or more. As the rocks all over eastern and central Pennsylvania are intensely folded, and as most of the beds rise to outcrop to the west or north of Pennsylvania, it is possible to measure and examine this great thickness of rock in many places in and outside the State. As most of the beds maintain fairly persistent character over long distances and as, by comparing the characters at one place with those at another place, it is possible to determine about what changes occur, one can estimate quite closely for any given place the general character and thickness of any bed, even though it be several thousand feet below the surface.

For example, the Pocono Mountains are underlain by a massive sandstone about 1100 feet thick. That sandstone turned on edge makes many of the mountains of central Pennsylvania, such as Second and Peters mountains on the Susquehanna, Terrace Mountain near Huntingdon, etc. In Second Mountain the Pocono sandstone has a thickness of about 1350 feet; it is 1130 feet near Altoona, 1175 feet near Lock Haven, 1000 feet near Foxburg in Clarion County, 920 feet near Latrobe, about 700 feet in Ohio, 675 feet in Susquehanna County, 575 feet in Tioga County, 250 feet on the Genesee River in New York, and so on. By plotting on a map the thickness at many localities, it is possible to estimate rather closely the thickness of the Pocono at any point in Pennsylvania where it occurs. If at the same time notes are made on the character of the sandstone, and if these show fairly uniform changes from east to west or north to south, one can judge fairly well as to its character under any spot on the surface where it is present. The thickness and character of many if not most of the other beds, but not all, can be determined this way, even where they are deeply buried. Some of the beds are so irregular in occurrence that it may not be safe to predict their occurrence at or under any spot, much less their thickness. They are where we find them. Thus, the Oriskany sandstone ranges from over 400 feet to nothing in thickness. It may be 6 feet in one section and 200 feet in the next. It is lacking in many sections. In northwestern Pennsylvania it ranges from 10 to 65 feet in thickness.

Thus it is possible, for most of the State, to arrive at the average thickness and character of each of the rock formations, and having determined the order and succession of these beds, it should be possible

to estimate the depth of any one of them at any place, provided we know just which rock occurs at the surface.

The geology of the whole State has been mapped in a general way, and about 35 per cent of the State has been mapped in detail. In these latter areas it is possible to estimate the depth of a given bed with some exactness, but in those areas where detailed mapping of the geology has not been done, some of the geologic formations are 2000 feet thick or more and, lacking knowledge as to where in such a thick formation a given spot on the surface may be, it is impossible to make a close determination of the depth of a given bed.

Nevertheless, it may be possible to say that at a certain spot the surface is immediately underlain by such and such a formation, which has such character and does or may contain such and such minerals of value. Then, knowing what formations underlie the surface formations in order, we may do the same by each in turn. In the end we have arrived at a description of all of the rocks underlying that spot to any desired depth and what minerals of value these rocks do or may contain.

In the southeastern and some of the central part of the State, the rocks have been so greatly folded and in many places so broken and pushed out of place that, except where detailed mapping is already completed, only an actual examination of the land will determine what rock outcrops at the surface. In such places also, the breaking or folding of the rocks may have been accompanied by the inflow of igneous rocks and mineral-bearing solutions which resulted in veins or other forms of mineral deposits, whose presence can be determined only by prospecting with pick or drill.

A number of new electric, magnetic and seismologic methods are being introduced by which it may be possible to determine the presence and depth of a mineral or of a given rock. These new methods have nothing in common with the old divining rods or doodle-bugs. The equipment is expensive and requires highly trained men to operate it.

The State Geological Survey has been functioning for nearly 100 years, but not continuously, and sometimes on very meager funds. It has, however, accumulated a very large amount of information, including the records of between ten and twenty thousand wells. The conclusions given in the chapters beyond are based on this accumulated information. In some of the counties, information is very complete; in others it is exceedingly meager. Detailed surface mapping and study of the mineral resources is being extended from year to year as fast as funds permit. In the meantime, and in addition to what is given in the following chapters, information may be gotten through the Survey reports, to be obtained from the Bureau of Publications or consulted in libraries; or a letter of inquiry, or a personal call on the Geological Survey, Harrisburg, may bring you more extensive and definite information than can be obtained from the reports. A third alternative is to employ a consulting geologist. The members of the Geological Survey may not do any private geologic field work in the State; but their experience and the information on file in the Survey office make it possible for them to render valuable service to taxpayers who are in need of advice on problems pertaining to geology and mineral resources; and names and addresses of competent consulting geologists will be furnished on request.

A MICROGRAPH OF PENNSYLVANIA'S UNDEVELOPED MINERAL RESOURCES

FUELS

Anthracite. Covers 484 sq. mi. in NE. Pennsylvania; 15 to 27 beds, 3 feet up to 114 feet thick (Mammoth bed averages 58 feet in Southern field); beds highly folded and crushed at south; less folded toward north. About 5 billion tons mined or lost since 1800; 9 billion tons estimated still recoverable. Future mining on thinner coals at greater depths (max. now 2200 feet), with more water to handle (now 9 to 12 tons per ton of coal); with increase of danger from gas, rock falls, etc. Coal will outlast another century.

Bituminous coal. Area west of Allegheny Mountain except in NW. corner of State; also Broad Top field and small areas in N. Pennsylvania. Beds 1 to 16 feet thick. Pittsburgh bed, 4 to 9 feet, unmined balance, nearly 8 billion tons. Most of unmined coal in other beds under 4 feet. Beds nearly horizontal. Mining by drift, slope, or shaft to depths commonly less than 500 feet. Total recoverable coal left, 44 billion tons (est.); will last 100 to 150 years at recent rates of mining. Exhaustion of thicker beds during next 75 to 100 years likely to turn much industry to other States and extend life of field.

Peat. Not studied; little recorded; confined to lakes and swamps in glaciated counties of NE. and NW. Pennsylvania.

Oil (petroleum). Production started 1859. Peak 1891 (31,400,000 bbls.); declined nearly to 7 million bbls. about 1920, then rose to 13 million bbls. in 1931 owing to rejuvenation by pressue in Bradford field. Oil west of line from NE. McKean Co. to SW. Fayette Co. only, and commonly to a depth of less than 3000 feet. Outlook: new wells will find oil within this area and depth; two-thirds of today's oil from Bradford field; rejuvenation methods not very successful elsewhere. Yield will decline to zero in 50 or 100 years, leaving much oil still in rock to be obtained by mining.

Natural gas. North and west of Allegheny Mountain only, with the main field some distance north and west of the mountains. Gas found to about 7400 feet. Much gas yet to be gotten by drilling deeper in old fields, though little yet found below 6500 feet. Deep drilling on anticlines may reveal additional pools. Will probably last 100 years yet.

Oil shale and oil from coal. Small bodies of bituminous or cannel shale in western Pennsylvania will yield from 5 to 50 gals. of oil to the ton; total not large. Gas coals of Pittsburgh district and northward yield 35 to 55 gals.

STRUCTURAL MATERIALS

Clays and shales. Quantity endless, considering all kinds. High-grade clay limited. White clay and kaolin in limited amount in SE. counties. Flint clay in lenses or lense-like beds in under-clays of Coal Measures; quantity small, but probably enough to supply industry for 100 to 150 years. Under-clays under all coal beds of the bituminous field, thickness 2 to 20 feet; will last indefinitely. Alluvial clays along streams, wide spread and abundant. Shales, 43 per cent of the sedimentary rocks of the State, widely scattered, mostly sandy or red.

Limestone and dolomite. Formation II of the 2nd Geol. Survey, up to 10,000 feet thick; Cambro-Ordovician age; underlies limestone valleys of eastern and central Pennsylvania; contains 3 beds 50 to 1000 feet pure limestone used for lime, flux, cement, etc. All used for local building; none classed as high-grade commercial building stone. Cement rock at top, in Lehigh Valley and west to Reading, basis of cement industry. Helderberg and adjoining limestones, basal Devonian, 50 to 600 feet thick; zigzag across center of State; supply local building stone, fertilizer, etc. Many beds in Coal Measures west of Allegheny Mountain; Vanport limestone in Beaver and Lawrence counties and eastward to Elk County, 1 to 20 feet thick, high-grade; used for cement, flux, lime, etc. Upper Freeport limestone in Pittsburgh region and northeastward; irregular, but locally high-grade. Other limestones of Coal Measures abundant in SW. counties, but not generally of high-grade.

Sandstone, bluestone, ganister, sand and gravel. Sandstones, 30 per cent of bedded rocks of Pennsylvania; widely distributed. Mostly shaly and unsuited for building or other purposes. Best sandstones: Homewood in lower Coal Measures, commercial building stone, glass sand, etc.; Pocono, local building stone; Oriskany, near base of Devonian, high-grade glass sand and other purposes; Tuscarora quartzite, base of Silurian, locally ganister, used for silica brick, local building, etc.; Berea sandstone in NW. counties, local value for building or possibly for commercial stone. Thin-bedded sandstone in upper Devonian, called bluestone, used for flagging.

Sand and gravel in river terraces and in outwash plains in glaciated region; much sand derived from crushing sandstone.

Granite and related rock. These include granite, gneiss, schist, gabbro, serpentine, diabase (trap), rhyolite, and other related rocks. Confined to the Piedmont area in SE. corner of State and Appalachian Mountain belt. Schists abundant from south Bucks Co. to south York Co. Other rocks local and limited in extent. Used extensively for local building, road material (trap). Some suitable for fine finish.

Slate, roofing granules. Slate confined to Lehigh Valley and near Peach Bottom. High-grade; will last many centuries. Not likely to be found elsewhere in commercial quality and quantity. Raw material for roofing granules made by grinding slate, greenstone, epidosite, or serpentine in Adams, York, and Lancaster counties; is abundant in South Mountain and eastward.

METALS

Iron. Cornwall deposit, magnetite, long worked, will last another 80 to 100 years. Extensive prospecting has failed to reveal other large deposits. Bedded siderite ore (Marcellus age) mined in Lehigh Co. for paint. Clinton red ore formerly mined in central counties. Chemung red ore in northern counties formerly mined. Limonite (brown) ore formerly mined all over State. Deposits now mined only ones likely to be mined in next 100 years unless other similar deposits are found. Bog ore in NW. counties, limited market. Carbonate ores formerly mined from Coal Measure shales of W. Pennsylvania.

Gold, silver, and copper. Recovered as a by-product of iron mining at Cornwall and some similar deposits. No gold or silver ores known

in State. Their occurrence not impossible, but improbable. Silver formerly recovered from Phoenixville lead deposits. Copper occurs in South Mountain area. No commercial deposits found yet. May be found or may exist at depth.

Lead and zinc. Lead formerly mined in limestone near Phoenixville, Chester Co., Pequea, Lancaster Co., and Sinking Valley, Blair Co. Specimens from other areas suggest possibility of other deposits. Extensive deposits of zinc south of Bethlehem, probably not exhausted. Also once mined NW. of Lancaster. Small quantities elsewhere, as near Sunbury, suggest possibility of other deposits.

Other metals. Manganese abundant as stains; has been mined in association with brown iron ore, some deposits of which carry as high as 10 per cent manganese; no large deposits known. Chromium once mined extensively in southern Lancaster Co. Other deposits may occur in SE. counties. Nickel once mined near Gap, Lancaster Co., probably not exhausted. Nickel minerals found elsewhere, but not as ores. Traces of cobalt in Chester and Lebanon counties; produced as a by-product of Cornwall iron ore deposits. Spots of carnotite (radium ore) near Mauch Chunk.

CHEMICAL MATERIALS

Salts. Brines are abundant in SW. counties where wells in Pittsburgh region yield salt, bromine, iodine, and sodium bicarbonate. Rock salt of Upper Silurian age underlies most of western Pennsylvania at depths of 6000 feet or more; less depths in northern counties.

Potash and phosphate. Potash obtained from furnace flue dust, not known in commercial deposits in State. Phosphate minerals once mined near Mount Holly Springs, Cumberland Co., near Reeds Gap, Juniata Co., and in Chester Co. No large deposits known.

Sulphur, pyrite. Sulphuric acid has been made from pyrite obtained as a by-product from coal mines and from Cornwall iron ore. No commercial deposits of pyrite known.

INDUSTRIAL MINERALS

Aluminum minerals, aside from clays and kaolin, occur in many areas. High-aluminum clays reported with flint clays in Coal Measures. Corundum once mined in serpentine belt. Epidote appears sparingly in SE. counties. No bauxite known in State.

Asbestos. Formerly mined in Delaware Co., found in small quantity in many places in SE. counties. Probably little, if any, commercial rock.

Magnesia. Made from dolomite which is abundant in SE. and central counties. A little native magnesite found, but not in minable quantities.

Barite. Occurs in small quantities. Non-commercial in several counties, associated with limestone.

Feldspar. Occurs in veins 6 to 25 feet wide in Delaware and Chester counties. Has been mined until recently.

Graphite. Occurs in gneiss; associated with Franklin limestone of pre-Cambrian age. Mined on small scale many years; not easily separated. Occurs in Bucks, Lehigh, Montgomery, Lancaster, Berks and other counties.

Mica. Abundant as small, scattered flakes in many rocks. A few large blocks have been found, but not in minable quantity.

Ocher, umber, and brown iron ore have been mined locally for paint pigment.

Quartz or silica. Occurs as vein quartz in SE. counties. Quantities small; also obtained by crushing pure sandstone or quartzite.

"Talc" and serpentine. Mined near Easton. Serpentine occurs in belt from Delaware to Lancaster counties near State line. Used for paint filler.

Garnet. Scattered abundantly in schists; locally has been gathered in a small way. Used as an abrasive.

MISCELLANEOUS MINERALS

Many other minerals occur as mineral specimens, but have not been found in commercial quantities, including allanite, beryl, cyanite, celestite, gems, greenockite, rutile, tourmaline, etc.

GROUND-WATER SUPPLIES

In general, the State is well supplied with ground waters. The best supplies are found in areas of glacial outwash and in river gravels. Areas underlain by sandstone come next, though salt water may be encountered with depth. The limestone areas may give abundant water or none according as water channels are struck or missed by drilling. Shale, granite, gneiss, and other very old rocks are commonly very fine-grained and contain water only in the cracks and crevices. These rocks may supply enough for household use, but not for industrial use.

Notice

A list of the Survey publications with price will be furnished on application.

The geology and mineral resources of Pennsylvania have been described more in detail in Bulletin G-1, Syllabus of Geology and Mineral Resources of Pennsylvania, to be obtained for 30 cents only from The Bureau of Publications, Market and 10th Streets, Harrisburg, Pennsylvania. Make checks payable to State Treasurer.